Cover Crops

Cover crops are essential to reduce or eliminate tillage, control weeds, and build soil carbon. Ideal cover crops are killed (by frost, mowing, crushing) before flowering, so they don't produce seeds. Their photosynthesis is an important source of soil carbon while living, and their biomass becomes available after they die. Legumes are important cover crops, as are long-rooted plants that bring nutrients from deep in the soil. Besides increasing soil carbon, cover crops also reduce nitrogen leaching, resist wind and water erosion, improve soil structure, increase water infiltration and reduce evaporation. Cover crop cocktails, mixes of various cover crop seeds, are excellent was to encourage biodiversity.

Diversity and Crop Rotation

Robust soil depends on a diverse soil microbial population. Microbial biomass is larger when legumes are included in the rotation. Animal manure is a valuable product of the small mixed farm, rich as it is in carbon and microbial biomass that inoculates the soil with microbes.

No Chemicals

Toxins like pesticides are lethal to many beneficial soil organisms, and the use of synthetic agricultural chemicals has been shown to be destructive of soil carbon. Water soluble fertilizers deplete soil organic matter by encouraging shallow roots, soil acidification, and obstructing the symbiosis between plants and soil microbes.

Pasture and Forests

Grazing on pasture is a highly effective way to restore soil carbon. Some people are concerned about ruminant animals giving off methane, a greenhouse gas. But in an ecological setting this is no problem as bacteria will quickly metabolize it. It is only when ruminants are away from biologically active soil or water, such as in feedlots or on soil where toxins have been applied, that ruminant methane emissions can be of concern. Some studies suggest woody plants are another way to deliver sizeable soil carbon gains.

Biochar

Soils enriched with char have a long term fertility that may be related to the protective habitats provided by char's internal spaces for microbes, or to its molecular structure, which creates a large capacity to retain ions of such minerals as calcium, potassium, and magnesium.

Benefits of Restoring Carbon to Soil

The advantages of restoring carbon your soil are not limited to removing carbon dioxide from the atmosphere.

Water - Increasing soil carbon builds aggregates, which in turn act as a sponge to enable soil to hold water, thus providing reserves in times when precipitation is low and a sink to soak up excess when it is high. This capacity to retain water also reduces the risk of erosion and crop loss.

Fungal Dominance - A high ratio of fungi to bacteria in soil is important to plant production. You have it if your soil smells mushroomy, not sour. It is the fungi that seek out and supply water and nutrients to plant roots as needed. Practices recommended here move soil toward fungal dominance.

Better Crops - Plants, like animals, have evolved complex defenses. Such abilities are strongest when the plant is healthy. Healthy plants also biosynthesize more of the volatile molecules and higher metabolites that produce the flavors and aromas of food crops. So restoring carbon to soils benefits all: farmers with larger yields, gardeners with tastier crops, and consumers with healthier food.

Conclusion

We have taken too much carbon from the soil, burned it, and sent it into the atmosphere as carbon dioxide. Even if we could stop burning fossil fuels tomorrow, the greenhouse gases already released will continue to raise global temperatures for many years.

We really have no alternative but to restore carbon to the soil. This can be done through biology, using a natural, time tested method. Farmers, gardeners, homeowners, landscapers, anyone who owns or manages land, can follow these simple principles and do both: restore carbon to the soil, and help rebuild the marvelous system that nature has put in place to renew our atmosphere -- while providing food, beauty and health for all creation.

This is a summary of a longer paper with sources. To read that or for further information on restoring soil carbon: www.nofamass.org/carbon

NOFA MASS Northeast Organic Farming Association

updated 8/14/15

Soil Carbon Restoration: Can Biology Do the Job?

by Jack Kittredge, NOFA/Mass policy director

How do we deal with greenhouse gas emissions and the resulting frequent weather extremes they have created? Clearly we must stop burning fossil fuels. But where can we put the carbon already in the air? There is only one practical approach -- to put it back where it belongs, in the soil. This will require all of us to help. We have written this short brochure to explain why and how carbon must be restored to the soil, and the advantages carbon-rich soils provide us.

Climate Change

Scientists believe that the cause of such unpredictable weather extremes is the buildup of manmade greenhouse gases in the atmosphere. Mostly carbon dioxide, but also other gases, they are emitted from soil and water into the atmosphere by natural processes. Those gases are also broken down by natural processes and returned to their sources in a continual cycle.

The concentration of a gas in the air is measured in units called "parts per million" (ppm). Throughout human history atmospheric carbon dioxide has stayed at roughly 280 ppm.

Human Disturbance of the Carbon Cycle

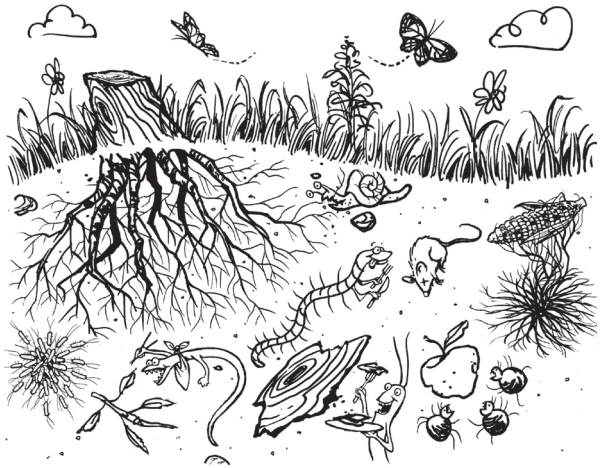
Since the dawn of agriculture some 12,000 years ago, however, human caused deforestation, land clearings and crop tillage have released excess carbon dioxide. With the burning of fossil fuels and industrialization of agriculture, these emissions have increased dramatically. Their level in the air now stands at 400 ppm.

We must curb our release of greenhouse gases. But that is not our only problem. Many scientists feel we must take

carbon out of the air as well. They feel 350 ppm is the most we can tolerate without extreme climate disruption. So we need to find a long term home for 50 ppm of carbon dioxide, which is 106 gigatons (Gt) of carbon.

But we can't store that carbon in the 70% of the planet that is covered with water. Carbon dioxide forms carbonic acid in water, which is already making the ocean too acid and killing many forms of sea life, including shellfish, corals, and plankton.

We must put the carbon in the soil, where the carbon came from and where it is needed. But let's understand the soil a little better.



Soil's Carbon Hunger and Photosynthesis

Soil is literally alive. It is full of bacteria, fungi, nematodes, protozoa, algae, and many, many other creatures. The huge appetites of these soil organisms for carbon means that they quickly consume all available organic matter in healthy soil.

But if carbon is so rapidly consumed in soil, then why does it not quickly vanish?

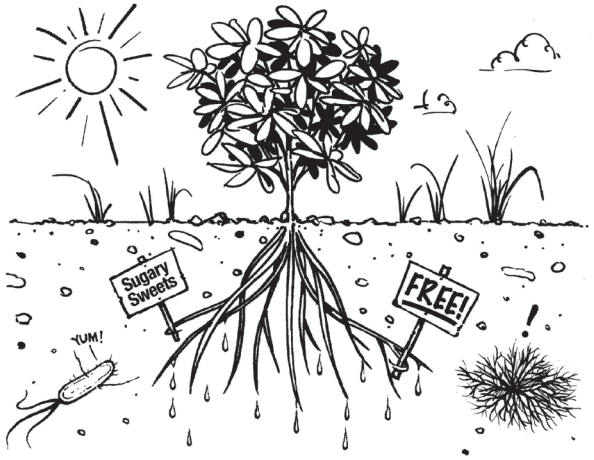
Because plants are constantly renewing the supply using their remarkable power to take carbon out of the air and put it into living matter. This, of course, is called photosynthesis.

The sheer scale of this process is impressive -- 15% of all carbon dioxide in the world's atmosphere moves through photosynthetic organisms each year!

All living things are carbon-based, and need to consume carbon to survive. If you can draw it out of thin air, as plants do, you have a commanding advantage. But even if you can't make carbon compounds, you must have them.

How else can soil microbes get carbon? They can "earn" it!

When plants photosynthesize and make carbohydrates they "leak" or exude a significant amount of these compounds as "liquid carbon" into the soil.



Root Exudates

Hungry soil organisms quickly show up to consume the tasty carbon-containing root exudates. But they soon want more. If a plant is strong it can exude more carbon.

So fungi find water and nutrients and transport them to the roots. Bacteria become chemists -- synthesizing hormones, fixing nitrogen, producing fungicides or antibiotics for the plants on demand. These relationships benefit both parties, at no cost.

Soil Aggregates

If you squeeze a handful of healthy soil, then release it, it should look like a bunch of peas. Those are soil aggregates. Inside those walls carbon exudates fuel lots of biological activity. Inside an aggregate it is moist and oxygen is scarce.These properties enable nitrogen-fixation and other biochemical activities to take place.

So, Can We Restore Enough Carbon to the Soil to Mitigate Weather Extremes in Time?

We know that 106 Gt of carbon will easily fit in the soil because that is where it came from. Land clearing and agriculture have brought out 136 Gt since 1750.

Many studies measure photosynthesis and soil carbon. They show:

- Perennial growing systems are great at restoring carbon.
- Row crop soils report lower carbon gains than pastures.
- Synthetic chemical fertilizers reduce or even eliminate soil carbon buildup. Manure and compost, however, do not.

The globe has 8.3 billion acres of grasslands and 3.8 billion acres of cropland. If each were managed using carbon-building practices, annually the grasslands could restore 21.6 Gt and the croplands 2.1 Gt. This totals 23.7 gigatons. Since we want to restore 106 Gt, we could do it in under 5 years!

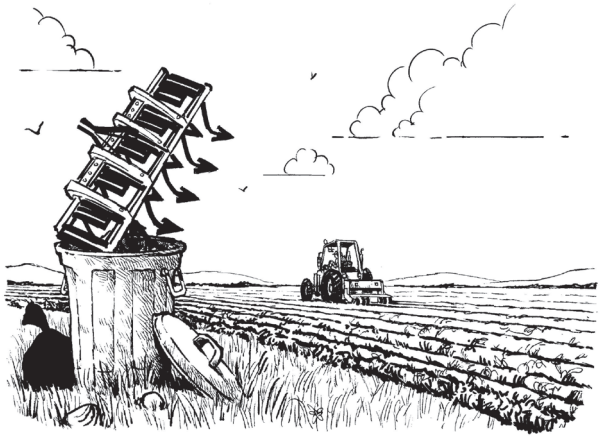
Stable Carbon

Of course if we want to restore a lot of carbon to the soil it has to be done so that it won't be oxidized. One form of carbon that seems to remain stable for years is humus. It is composed of complex molecules containing carbon, but is not easily broken down by soil life. This is controversial, but many scientists believe that microbes produce humus in soil aggregates from liquid carbon. So, to restore carbon means not just adding organic matter to your soil. That will help microbes and can make crops flourish. But to build long term carbon, you need to do more.

Here are the practices that build long term carbon in soil:

Keep Soil Planted

Bare soil burns carbon, plants protect it by forming a barrier between air and soil. Growing plants are also your best protection against erosion. And plants add to soil carbon through their power of photosynthesis. Every square foot of soil that is left exposed – between rows of crops or in a fallow field – reduces your carbon bank account.



Minimize Tillage

Organic growers do lots of tillage for weed control. But it stirs up soil and oxidizes it. Tillage also rips up the fungal hyphae that carry water and nutrients to plant roots. Soil aggregates will be ruined by tillage, as will pore spaces in the soil that hold air and water.